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CONTRACT NAS 9-14451

FINAL REPORT - PART I

Development of an Expanded Core Structural Panel for
Spacecraft Interior Applications

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(NASA-CR-144523) DEVELOPMENT OF AN EXPANDED
 CORE STRUCTURAL PANEL FOR SPACECRAFT
 INTERIOR APPLICATIONS, PART 1 Final Report
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1. COST AND SOURCES OF THE PANEL SHEET STOCK

- a. Material procured: 50 sheets of polyethersulfone, .508 mm (.020") thick, 762 mm x 1108 mm (30" x 43-5/8")
- Source: Rowland Products
Kensington, Conn. for extruded sheet material

ICI (United States), Inc.
Wilmington, Delaware for basic PES resin
- Cost: \$1,400 for 50 sheets = \$28.00/sheet
(approx. \$44/kg, \$20/lb)
- This cost was for a developmental extrusion run for a small quantity of material.
- Estimated cost of production quantities -
\$22 - 26/kg (\$10 - 12/lb) based on a resin cost of \$12/kg (\$5.50/lb).
- b. Material procured: PF 105 fiberglass insulating batt material
- Source: Owens-Corning Fiberglas Co.
- Cost: Approximately \$2.69/sq.m (\$.25 per sq.ft.)

2. SUMMARY OF THE ACTIVITIES WHICH RESULTED IN THE FINAL FABRICATION PROCESS

Once the materials were procured, it was necessary to assure proper equipment accommodation. Past experience with forming Quadricore of the higher temperature engineering thermoplastic materials (polycarbonate, polysulfone), a study of the resin manufacturer's specifications, and from recommendations of the extruder of the sheet material, shortened the time required for determining optimum heat, temperature, drying, dwell and cooling times.

Consequently, shop time was devoted to the following:

- a. Drying oven - increase temperature limit capacity.
- b. Quadricore press - pre-heat station modified to attain higher temperatures and uniform distribution of heat to eliminate cold spots.
- c. Heat controllers for manifold - changed to permit increase in manifold heat and die temperatures.
- d. Careful realignment of press.
- e. Radius of pins increased - to facilitate and improve flow of material from the nodes to give more uniform wall thickness.
- f. Strengthen clamp frames for holding the sheet material.

3. DETAILS OF THE FINAL FABRICATION PROCESS INCLUDING PRE AND POST TEST CONDITIONING ENVIRONMENTS, MOLD MATERIAL, MOLD TEMPERATURE, MOLD RELEASE AGENT, FORMING PRESSURE, AND ANY OTHER DETAILS PERTINENT TO FORMING THE SUBJECT MATERIALS.

During the past three years the contractor has formed core for sandwich panel applications using a wide variety of thermoplastic sheet materials of various gauges from .254 mm (.010") to 1.524 mm (.060"). Excellent core resulted from those materials which manifest good elongation characteristics: modified polystyrene (medium to high impact), ABS, polycarbonate, polysulfone, and polyvinylchloride. The polyolefins, although readily formable, lack two of the more desirable characteristics for Quadricore: bondability and a stiff membrane structure. A limited effort has demonstrated the feasibility of obtaining excellent core from superplastic metals. Samples of opposed-pin core and panels have been produced with stainless steel alloys having a micro duplex eutectoid structure, a superplastic zinc aluminum alloy (Z400) and Titanium (Ti 64). Forming of Quadricore from these superplastic metals at the required higher temperatures utilizing creep characteristics necessitated the construction of oven-enclosed facilities.

Although polyethersulfone was formed into Quadricore on existing equipment, due to its elevated heat distortion temperature, above 203° C (398° F), and hygroscopicity it was necessary to make modifications to the drying oven, the pre-heat section of the press, the tooling plates, and existing clamping frames.

DESCRIPTION OF THE PROCESS:

The Quadricore tooling utilized for the forming of PES consists of upper and lower platens onto which are affixed a die containing an array of aluminum pins of 12.7 mm (1/2") diameters, with a distance between the centers of adjacent pins of 12.7 mm (1/2"). This optimum pin distance results in a core configuration of an infinite series of rectilinear trusses around each node, regardless of the overall depth of the core. One die of pins bottoms out on the opposite platen to give a maximum core depth of 12.7 mm (.500"). An overlay of shims on the bottom platen reduced the overall core depth to a desired height of 11.4 mm (.450"). A precise positioning of the pins in each platen, proper positioning of the platens in relation to each other, and a vertical, parallel motion of the platens closing toward each other are paramount considerations in forming a Quadricore sheet with uniformity and integrity.

The dimensional capacity of the Quadricore press utilized on the contract yields a trimmed sheet size of 635 mm x 1016 mm (25" x 40"). Clamps, on four sides for semi-automatic operation, hold a thermoplastic sheet 762 mm x 1108 mm (30" x 43-5/8").

Prior to insertion in the clamp frame the thermoplastic sheet of .508 mm (.020") nominal gauge PES was dried out in oven for four hours at 170° C (338° F).

Trial and error of temperature preheat in the press oven determined the heating parameters to be between 260° C (500° F) or 300° C (570° F), and a pre-heat soak of approximately 15 seconds, at the end of which interval the increasing sag in the material required a quick shuttle of the frame to the die area and a smooth closing of the dies to form the core.

3. DETAILS OF THE FINAL FABRICATION PROCESS (contd),
DESCRIPTION OF THE PROCESS:

A die temperature of 191⁰ C (375⁰ F) was found to be optimum. After 45 seconds, the time needed for the PES material on the dies to cool below deformation temperature, the dies are opened and the clamping frame, with formed PES material, is removed. No release agent was used nor required, as the geometry of the core is such that contact of the material with the dies is only at the top radii of the die pins. The formed sheet is removed from the clamping frame and is then ready for edge trimming and the bonding of face sheets.

The pressure required to close the dies is affected by the temperature of the material and the forming area between dies. The upper dies in the press are stationary and the press force used is that necessary to raise the platen with the lower die and elongate the material in its softened condition. Some trial and error was necessary to determine at what point in time the temperature of the material was above its heat distortion point but below the temperature of uncontrollable sag.

Die dimensions:	.645 sq.m (1000 sq.in)
Line pressure:	59 kg (130 lbs)
Air cylinder diam:	30.48 mm (12")
Resulting pressure:	1.033 kg/sq.cm. (14.7 lbs/sq.in.)

The technical problems encountered in forming PES Quadricore and their solutions were described in monthly reports dated 6 March 1975 and 1 April 1975, as follows:

Production type dies were refurbished to permit continued high temperature runs of polyethersulfone and attain closer overall depth tolerances over the full sheet. Base plate heat was increased to permit the 260⁰ C (500⁰ F) die temperature predicted for forming NR140 material should it become available. This accommodation of equipment was performed prior to receiving information on the non-availability of NR140 sheet and that the requirement would be cancelled. To obtain more uniformity of node thickness in the forming of polyethersulfone, it was necessary to radius the die pin edges, maintain a more uniform die temperature, and submit the heat to the sheet material more gradually. When using 6.35 mm (1/4") node diameter, to optimize core strength, it was found advisable to reduce the overall core height from 12.7 mm (.500") to 11.4 mm (.450").

DELIVERED FINISHED PANELS:

Pursuant to Para. 3.4 of Exhibit "A" to the Contract an end item panel was delivered of .508 mm (.020") nominal gauge PES formed with 6.35 mm (1/4") diameter nodes and having an overall depth of 11.4 mm (.450"). A face sheet

3. DETAILS OF THE FINAL FABRICATION PROCESS (contd),
DESCRIPTION OF THE PROCESS:

of .508 mm (.020") PES was bonded to the core nodes with Epon 934 epoxy adhesive applied only to the nodes and cured by vacuum bag technique. Various methods of bonding face sheets to PES Quadricore were tried and reported in the monthly report dated 22 May 1975.

The non-availability of Dupont NR140 aromatic chlorinated polyether was previously reported and, pursuant to NASA Contracting Officer letter dated March 21, 1975, an end item panel of Quadricore with PF105 acoustic insulation was substituted to satisfy the requirement of para. 1.2.1.2 of the Statement of Work. 30.48 mm (12") squares of 12.7 mm (1/2") thick PF105 fiberglass were die cut to fit over the nodes on one side of a PES Quadricore sheet, and to the nodes of which a fly screen impregnated with an epoxy adhesive was bonded at elevated temperature. The resulting sample panel, although demonstrating the concept, was structurally sub-marginal and not conclusive for practical application. An opposite face sheet of Kevlar, with an epoxy type prepreg adhesive, was bonded to the panel to demonstrate the potential for this acoustical panel. The more apparent major deficiencies of the submitted panel are the low-peel strength of the fly screen-to-node bond and the warping of the panel due to the dissimilar face sheet materials. Subsequent development has pointed to methods for obtaining satisfactory bond strength and freedom from warping. Face sheets of materials having similar coefficients of expansion when bonded to Quadricore by means of reticulating film adhesives yield the most satisfactory panels.

4. REPRESENTATIVE COSTS FOR FORMED PANELS OF THE SUBJECT MATERIALS

	<u>COST PER SQ.M</u>	<u>COST PER SQ.FT.</u>
a. Material costs:		
(assumption: PES to be procured in moderate extrusion quantities - 454 kg (1,000 lbs) - estimated cost- \$22 - 26/kg. (\$10-12/lb)		
Using \$24.25/kg (\$11/lb) - .508 mm (.020") material thickness, 762 mm (30") x 1108 mm (44") sheet size to produce .645 sq.m. of core (7 sq.ft) - weight .617 kg (1.36 lbs) yield - .645 sq.m.(7 sq.ft.) of core.		
.617 kg (1.36 lbs) @ \$24.25/kg (\$11/lb) = \$14.96/sheet = 1496 ÷ .645 sq.m (7 sq.ft) =	23.19	\$ 2.14
b. Labor costs:		
15 sheets/hr for forming and trimming, 1 operator, 1 inspector @ \$30/hr = \$2.00/sheet ÷ .645 sq.m (7 sq.ft.) =	3.10	.29
c. Total costs:	\$ 26.29	\$ 2.43
Purchasing burden @ 8% G & A and profit @ 30% 38% (cost ÷ .62)	\$ 42.40	\$ 3.90
d. Kevlar facing - .01 mm (.004") thick		
facing @ \$.25/mm (\$23.00/yd)	\$ 21.50	\$ 2.00
adhesives @ \$3.23/sq.m (\$.30/sq.ft)	3.23	.30
	<u>\$ 24.73</u>	<u>\$ 2.30</u>
x 2 =	\$ 49.46	\$ 4.60
labor - 10 panels/hr @ \$30/hr ÷ .645 sq.m (7 sq.ft.)	4.65 <u>\$ 54.11</u>	.43 <u>\$ 5.03</u>
Purchasing burden @ 8% G & A and profit @ 30% 38% (cost ÷ .62)	\$ 87.27	\$ 8.11
OVERALL COST	<u>\$129.67</u>	<u>\$12.01</u>